Analysis of 3 Custom Heuristics against baseline ID_Improved

A. Results of Running the Tournament (5 rounds)

```
                    **************************
                         Playing Matches
                    **************************

 Match #   Opponent     AB_Custom   AB_Custom_2  AB_Improved  AB_Custom_3
                        Won | Lost   Won | Lost   Won | Lost   Won | Lost
    1       Random       9  |   1     9  |   1     8  |   2     9  |   1
    2       MM_Open      3  |   7     8  |   2     8  |   2     3  |   7
    3      MM_Center     8  |   2     8  |   2     9  |   1     9  |   1
    4     MM_Improved    8  |   2     7  |   3     7  |   3     3  |   7
    5       AB_Open      3  |   7     5  |   5     4  |   6     3  |   7
    6      AB_Center     5  |   5     7  |   3     6  |   4     4  |   6
    7     AB_Improved    4  |   6     4  |   6     5  |   5     4  |   6
----------------------------------------------------------------------------
           Win Rate:      57.1%        68.6%        67.1%        50.0%
```

```
                    **************************
                         Playing Matches
                    **************************

 Match #   Opponent     AB_Custom_4   AB_Custom_2  AB_Improved  AB_Custom_3
                        Won | Lost   Won | Lost   Won | Lost   Won | Lost
    1       Random      10  |   0     9  |   1    10  |   0     8  |   2
    2       MM_Open      9  |   1     8  |   2     6  |   4     6  |   4
    3      MM_Center    10  |   0     9  |   1     9  |   1    10  |   0
    4     MM_Improved    7  |   3     5  |   5     6  |   4     6  |   4
    5       AB_Open      6  |   4     5  |   5     4  |   6     4  |   6
    6      AB_Center     3  |   7     6  |   4     4  |   6     5  |   5
    7     AB_Improved    5  |   5     8  |   2     5  |   5     3  |   7
----------------------------------------------------------------------------
           Win Rate:      71.4%        71.4%        62.9%        60.0%
```

```
                    **************************
                         Playing Matches
                    **************************

 Match #   Opponent     AB_Custom_4   AB_Custom_2  AB_Improved  AB_Custom_3
                        Won | Lost   Won | Lost   Won | Lost   Won | Lost
    1       Random      10  |   0    10  |   0    10  |   0     9  |   1
    2       MM_Open      7  |   3     8  |   2    10  |   0     6  |   4
    3      MM_Center     8  |   2     8  |   2     9  |   1     8  |   2
    4     MM_Improved    8  |   2     8  |   2     7  |   3     4  |   6
    5       AB_Open      4  |   6     7  |   3    10  |   0     2  |   8
    6      AB_Center     7  |   3     6  |   4     4  |   6     4  |   6
    7     AB_Improved    4  |   6     5  |   5     3  |   7     6  |   4
----------------------------------------------------------------------------
           Win Rate:      68.6%        74.3%        75.7%        55.7%
```

```
                    **************************
                        Playing Matches
                    **************************

 Match #    Opponent      AB_Custom_4    AB_Custom_2   AB_Improved   AB_Custom_3
                          Won  | Lost    Won  | Lost    Won  | Lost    Won  | Lost
    1        Random        10  |   0     10  |   0      9  |   1      9  |   1
    2        MM_Open        7  |   3      7  |   3      6  |   4      5  |   5
    3       MM_Center      10  |   0      9  |   1      8  |   2      7  |   3
    4     MM_Improved       8  |   2     10  |   0      8  |   2      5  |   5
    5        AB_Open        3  |   7      4  |   6      3  |   7      4  |   6
    6       AB_Center       5  |   5      4  |   6      7  |   3      5  |   5
    7     AB_Improved       4  |   6      8  |   2      6  |   4      3  |   7
-----------------------------------------------------------------------------
           Win Rate:      67.1%        74.3%        67.1%        54.3%
```

```
                    **************************
                        Playing Matches
                    **************************

 Match #    Opponent      AB_Custom_4    AB_Custom_2   AB_Improved   AB_Custom_3
                          Won  | Lost    Won  | Lost    Won  | Lost    Won  | Lost
    1        Random        10  |   0     10  |   0     10  |   0      8  |   2
    2        MM_Open        7  |   3      7  |   3      7  |   3      5  |   5
    3       MM_Center       9  |   1      7  |   3      9  |   1      7  |   3
    4     MM_Improved       7  |   3      6  |   4      4  |   6      5  |   5
    5        AB_Open        6  |   4      6  |   4      5  |   5      5  |   5
    6       AB_Center       7  |   3      6  |   4      7  |   3      3  |   7
    7     AB_Improved       3  |   7      4  |   6      5  |   5      7  |   3
-----------------------------------------------------------------------------
           Win Rate:      70.0%        65.7%        67.1%        57.1%
```

A.1 Analysis of Results

1. The heuristic (AB_Custom_2) : 2 * own_moves - opp_moves, which is a slight variation over ID_Improved performed slightly better than AB_Improved.
2. As one would expect in general, agents using AB Pruning with ID have a higher percentage of Wins over Agents that use MiniMax and/or Random Agents due to the ability to prune the game tree when searching for a good next move.

A.2 Recommendation of Heuristic

My recommendation of the preferred heuristic is AB_Custom_2. The criteria used for the recommendation is as below

1. Best Mean Performance in a sample of 4 tournament runs across different heuristics

	AB_Improved	AB_Custom_2	AB_Custom4	AB_Custom_3
Mean	68.2	71.425	69.275	56.775

2. Low cost of computation compared to other heuristics

3. Best Percentage of Wins against different Opponent heuristics (Random, MM_Open, MM_Center, MM_Improved, AB_Open, AB_Center, AB_Improved) across multiple tournament runs.

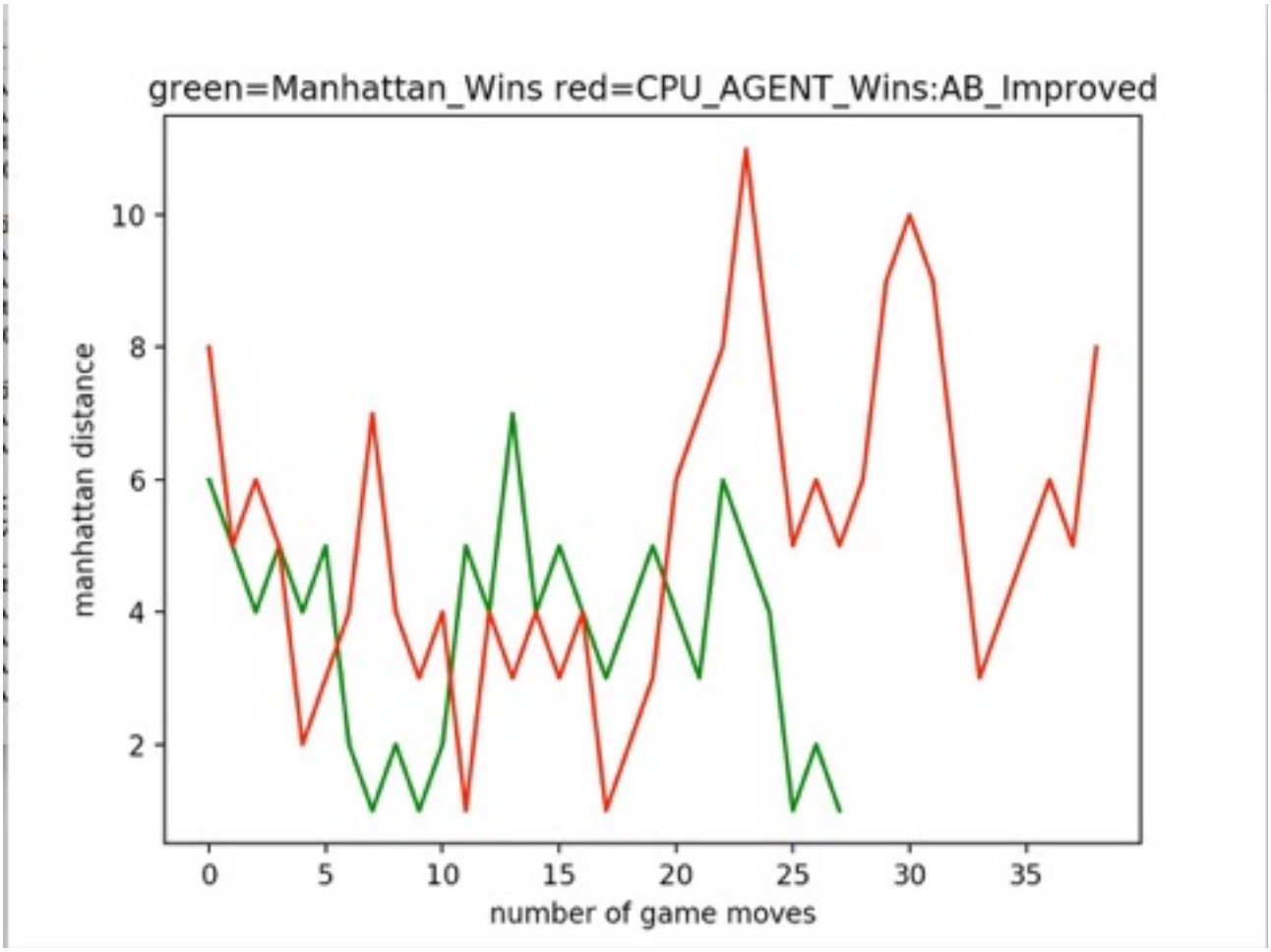
	AB_Improved	AB_Custom_2	AB_Custom4	AB_Custom_3
Worst Win % recorded	30%	40%	30%	20%

B. Analysis of Heuristics Implemented

B.1. AB_Custom_3 : Minimize Manhattan Distance

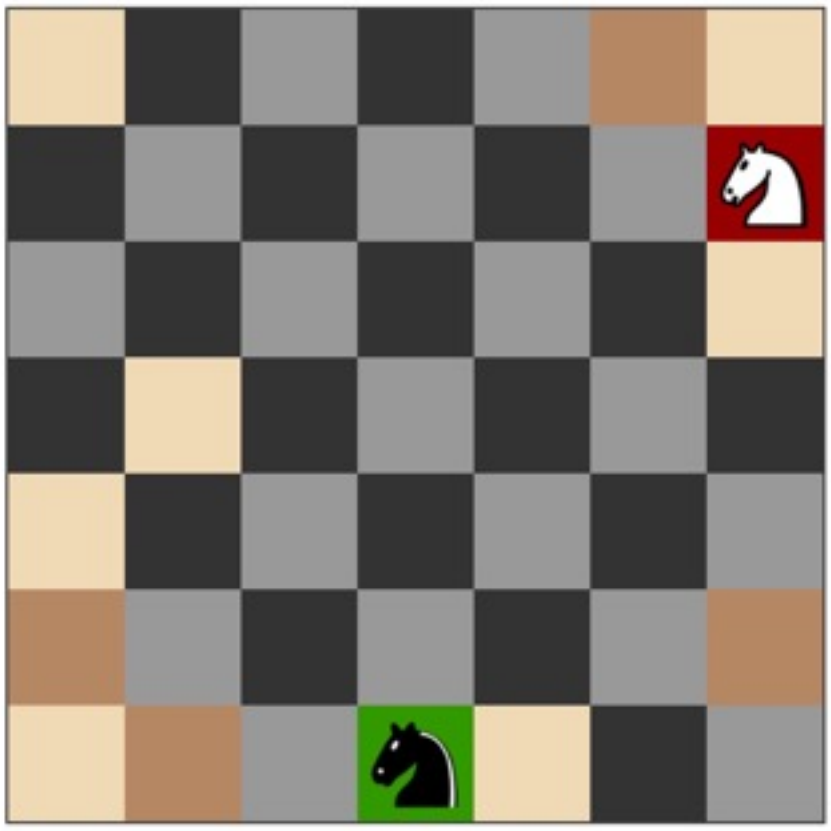
This heuristic takes the distance between the two players and minimizes it. Manhattan distance method is used to calculate the distance between the two squares (as they can move in L-shaped fashion, and this way of measuring is close to approximating that). The idea behind this heuristic is, typically the distance between the players gets smaller towards the end of the game. An adversarial agent would try to block the moves of the opponent, and will be actively trying to get closer to them as the result.

In the graph below shows that each step the heuristic tried to reduce the distance between the players. IOW the Agent implemented was trying to block the movement of the opponent by trying to get closer.



When the Agent actually lost against the CPU Agent (ID_Improved) it appeared that at least in this case the game was reaching an END-GAME where both players had only a single move left and since the CPU Agent was the second player it was

Player1	Player2
(1,4)	(5,2)
(3,5)	(4,4)
(2,3)	(3,6)
(1,1)	(1,5)
(0,3)	(3,4)
(2,4)	(4,2)
(1,2)	(3,0)
(3,3)	(5,1)
(4,1)	(3,2)
(6,2)	(2,0)
(5,4)	(0,1)
(6,6)	(1,3)
(4,5)	(2,1)
(5,3)	(0,2)
(6,5)	(1,0)
(4,6)	(2,2)
(2,5)	(4,3)
(0,4)	(5,5)
(1,6)	(6,3)

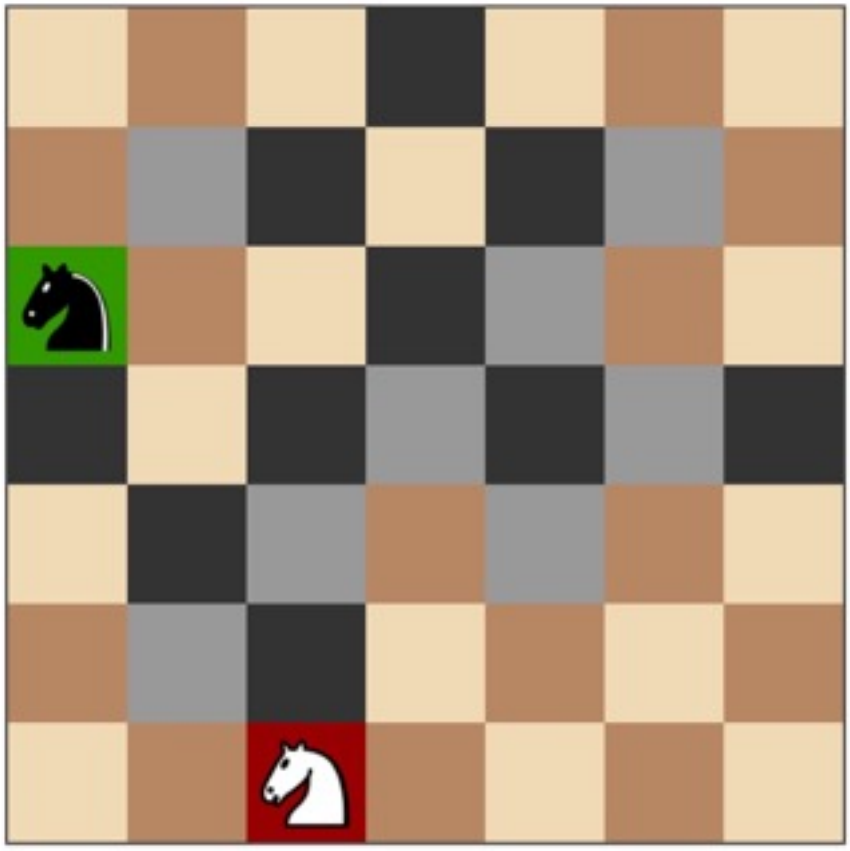


declared the Winner.

However there was a possible timeout before this heuristic could explore a better move which existed at Move number 21. At this point the heuristic should have caused a move to (5,0) as per the minimize Manhattan Distance criteria but it moved to (5,4) instead. Potentially a re-ordering of available moves may have helped here ?.

Having said that the Manhattan distance is not good enough to ensure a consistent win. It will try to reach a local optima as it is not partition aware

Player1	Player2
(1,4)	(5,2)
(3,5)	(4,4)
(2,3)	(3,6)
(1,1)	(1,5)
(0,3)	(3,4)
(2,4)	(4,2)
(1,2)	(3,0)
(3,3)	(5,1)
(4,1)	(3,2)
(6,2)	(2,0)



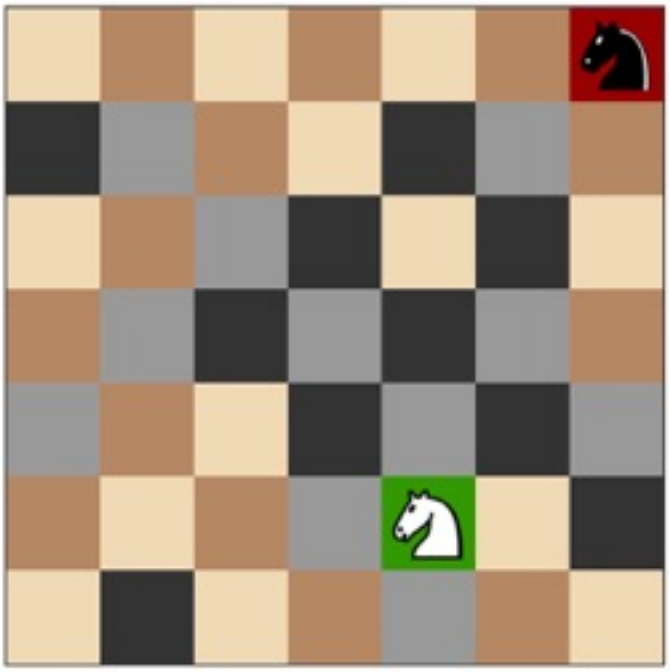
and might miss seeing a potentially larger free space in its pursuit to obstruct the opponent.

B.2. AB_Custom – Increasing aggressivity : Preserve Self Mobility in Beginning and Focus of Restricting the Opponent towards the EndGame

Given that blocking the opponent is not really feasible at the beginning of the match, we concentrate on preserving our own mobility at first, then gradually increase the focus on limiting the opponent's moves. (1 – game_ratio) * own_moves * 4.0 – game_ratio * opp_moves. where game_ratio is the approximate completion of the game (increasing over time).

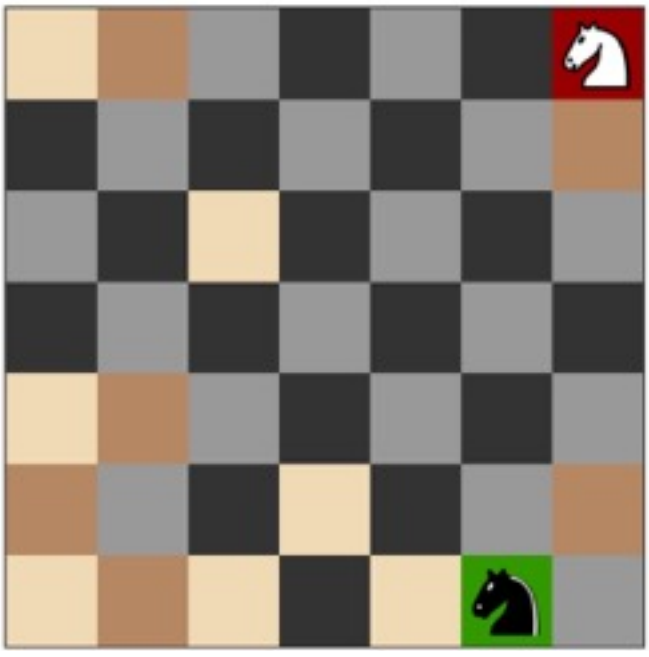
In my testing this heuristic stood third best in success rate at 57% after AB_Custom_2 and AB_Custom_4. And performed worse than the baseline AB_improved. The heuristic is capable of getting a win at Mid Game, though most of the times it appeared that for an Agent that is playing first, the win happened closer to the End Game.

Player1	Player2
(4,4)	(5,3)
(5,6)	(6,1)
(3,5)	(4,0)
(1,4)	(3,2)
(2,2)	(1,1)
(1,0)	(2,3)
(3,1)	(1,5)
(4,3)	(3,4)
(6,4)	(4,6)
(4,5)	(2,5)
(3,3)	(0,6)
(5,4)	

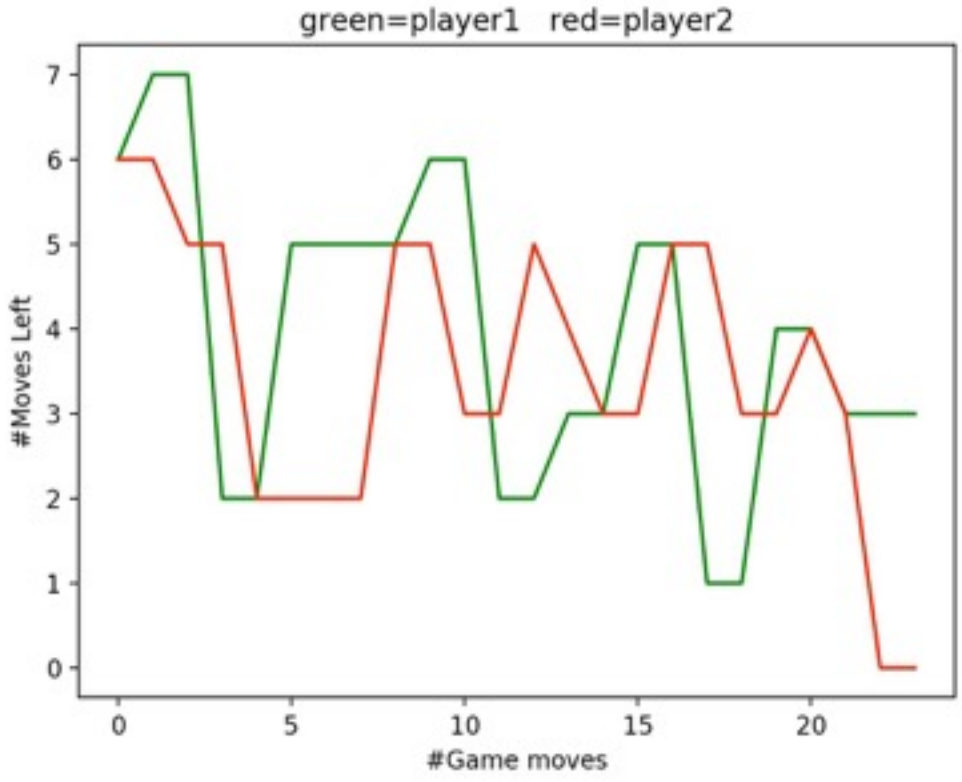


The same seemed to be true when the Agent lost to an ID_Improved adversary. The loss happened most of the times close to the End Game.

Player1	Player2
(3,4)	(2,0)
(5,5)	(1,2)
(3,6)	(0,4)
(1,5)	(2,3)
(0,3)	(3,1)
(1,1)	(1,0)
(3,0)	(0,2)
(4,2)	(2,1)
(6,3)	(3,3)
(5,1)	(5,2)
(4,3)	(4,4)
(3,5)	(3,2)
(1,4)	(2,4)
(2,6)	(4,5)
(0,5)	(6,6)
(1,3)	(5,4)
(2,5)	(4,6)
(0,6)	(6,5)



The picture below shows the functioning of the heuristic where it tries to increase its mobility (player1-green) in the beginning and focus on restricting the opponent (player2-red) as the game moves forward. This was for a case where the heuristic resulted in a Mid Game win for the Agent



B.3. AB_Custom_2 : Defending mobility : This first heuristic is a variant of the basic cost/benefit analysis

In this variant, we prioritize our own mobility over obstruction of the opponent by computing: 2 ∗ own_moves − opp moves. This gives results similar to our baseline ID_improved player (60% success against other heuristics). In particular in the round of tournament results shown in section A above, this heuristic achieved a 68.6% success rate against the other heuristics.

In general the ID_Improved seems to be a good heuristic as it is capable of providing a somewhat consistent ~60% success rate. This variation of ID_Improved seems to improve the success rate a little bit.

B.4 AB_Custom_4 : This is a variant of ID_Improved where we try to restrict the opponent early on (Initial Game) by choosing moves where own moves are a factor X more than the opponent and gradually reduce the factor X as we move towards Mid and End Game and concentrate on own mobility in Mid to End game.

The Factor X was defined as : 10 / (move_count + 1)

This heuristic achieved about 68 to 70 % wins against other heuristics. However it suffers from the same shortcomings as with AB_Custom in the sense that the variation in percentage of Wins against different opponent heuristics is from 30% to 100%.